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METERING AND PACKAGING OF CONTROLLED RELEASE MEDICATION

Field of the Invention

The present invention relates to the packaging of dry powders and particularly to the metering and packaging of precise quantities of pharmaceuticals and drugs for medical uses. The invention has particular utility in the metering and packaging of dry powders, particularly precise amounts of dry powder pharmaceuticals and drugs, and will be described in connection with such utility, although other utilities are contemplated.

Background of the Invention

The convenience of administering a single dose of a medication which releases multiple active ingredients in a controlled fashion and in a chosen location over an extended period of time, as opposed to the administration of a number of single doses at regular intervals, has long been recognized in the pharmaceutical arts. The advantage to the patient and clinician in having consistent and uniform blood levels of medication over an extended period of time are likewise recognized. The advantages of a variety of controlled-release dosage forms are well known. Among the most important advantages are: (1) increased contact time for the drug to allow for local activity in the stomach, small intestine, colon, or other locus of activity; (2) increased and more efficient absorption for drugs which have specific absorption sites; (3) the ability to reduce the number of dosages per period of time; (4) employment of less total drug; (5) minimization or elimination of local and/or systemic side effects; (6)

1 minimization of drug accumulation associated with chronic dosing; (7) improved
2 efficiency and safety of treatment; (8) reduced fluctuation of drug level; and (9) better
3 patient compliance with overall disease management.

4 Additionally, many experts believe controlled release drug delivery has many
5 important non-therapeutic ramifications as well, including a financial saving to the
6 patient in terms of fewer lost work days, reduced hospitalization and fewer visits to the
7 physician.

8 It is known that certain design parameters are critical to proper drug delivery.
9 Typically, they are: (1) delivering the drug to the target tissue; (2) supplying the drug
10 for a predetermined period of time; and (3) fabricating a delivery system that provides
11 drug in the desired spatial and temporal pattern. Controlled release drug delivery
12 systems are intended to utilize these parameters to achieve the aforementioned
13 advantages as compared to conventional pharmaceutical dosing.

14 Previously direct placement of medication onto a substrate generally was limited
15 to medical placement of large doses or required technology where the active
16 pharmaceutical was mixed with the substrate or matrix to provide differential delivery,
17 or coated with a material with desired release characteristics.

18 As used herein "controlled-release" is used to describe a system, i.e. method and
19 materials for making an active ingredient available to the patient in accordance with a
20 preselected condition, i.e. time, site, etc.. Controlled-release includes the use of
21 instantaneous release, delayed release and sustained release. "Instantaneous release"

1 refers to immediate release to the patient. "Delayed release" means the active
2 ingredient is not made available until some time delay after administration. Typically,
3 dosages are administered by oral ingestion, although other forms of administration are
4 contemplated in accordance with the present invention. "Sustained release" refers to
5 release of active ingredient whereby the level of active ingredient available to the
6 patient is maintained at some level over a period of time. The method of effecting each
7 type of release can be varied. For example, the active-ingredient can be placed on a
8 semi-permeable membrane having predetermined diffusion, dissolution, erosion or
9 breakdown characteristics.

10 Alternatively, the active ingredient can be masked by a coating, a laminate, etc.
11 Regardless of the method of providing the desired release pattern, the present invention
12 contemplates delivery of a controlled-release system which utilizes one or more of the
13 "release" methods and materials. Moreover, the present invention advantageously can
14 be employed in the development of multiple different release system(s).

15 The patent and scientific literature is replete with various sustained release (SR)
16 methods and materials. For common methods of obtaining SR systems, see "Sustained
17 and Controlled Release Drug Delivery Systems," Robinson, Joseph R., Ed., PP 138-171,
18 1978, Marcel Dekker, Inc. New York, NY. For example it is known to fill polymeric
19 capsules with a solid, liquid, suspension or gel containing a therapeutic agent which is
20 slowly released by diffusion through the capsule walls. Heterogeneous matrices, for
21 example, compressed tablets, control the release of their therapeutic agents either by

1 diffusion, erosion of the matrix or a combination of both. Other SR systems focus on the
2 fabrication of laminates of polymeric material and therapeutic agent which are then
3 formed into a sandwich, relying on different diffusion or erosion rates to control release
4 of the therapeutic agent. Liquid-liquid encapsulation in a viscous syrup-like solution of
5 polymer also has been known to be useful in controlling release of the therapeutic
6 agent. Additionally, it is generally known that heterogeneous dispersions or solutions
7 of therapeutic agents in water-swellable hydrogen matrices are useful in controlling the
8 release of the agent by slow surface-to-center swelling of the matrix and subsequent
9 diffusion of the agent from the water-swollen part of the matrix.

10 During dissolution of a controlled-release matrix tablet, the dosage form
11 generally remains as a non-disintegrating, slowly eroding entity from which the
12 therapeutic agent leaches out, through a diffusion controlled process. Conventional SR
13 formulations are generally designed to release their active ingredients over an extended
14 period of time, usually 8-24 hours. Conventional SR formulations use waxes or
15 hydrophilic gums as the primary drug carriers to prolong the release of the active
16 ingredients.

17 Starch USP (potato or corn) is commonly used as a component in conventional
18 tablet or hard shell capsule formulations.

19 The existing sustained release technologies generally involve relatively
20 complicated formulations and manufacturing processes which often are difficult and
21 expensive to precisely control. For example, one well known SR delivery system, OROS,

1 marketed by the Alza Corporation, involves laser drilling through a tablet to create
2 passages for the release of the drug from the tablet core. In controlled release
3 technologies, it is desirable to be able to incorporate the active ingredient in its
4 controlled-release pattern in a single dosage unit without deteriorating the active
5 ingredient. Moreover, the dosage unit should be able to deliver the system without
6 interfering with its release pattern.

7 Various methods have been devised to enable controlled-release systems to be
8 delivered to a patient without destruction of the delivery system during manufacturing,
9 handling and distribution. For example, controlled-release systems have been provided
10 in the form of beads or particles which are packaged in a gelatin capsule for oral
11 dosage. This method of delivery of the controlled-release system prevents damage to
12 the coating on the beads.

13 Furthermore, when controlled-release active ingredients are incorporated in
14 compression tablets, it may be difficult for many people to swallow such tablets.
15 Moreover, dissolution of high compression tablets often initially is slow and erratic and
16 may result in localized hot spots of alimentary tract irritation where disintegration and
17 release of the active ingredient finally occurs. And, present systems do not allow for the
18 accurate deposition of doses of powdered medication onto different substrates either in
19 single packets, layered packet, or multipackets on the same plane of the base substrate.

20 The present invention overcomes the disadvantages of the prior art by offering a simple

1 and inexpensive means of incorporating active ingredient (the drug) with a multitude
2 of controlled-release systems.

3 In our earlier U.S. Patent 5,699,649, granted December 23, 1997, we describe a
4 method and apparatus for packaging microgram quantities of fine powders such as
5 pharmaceuticals using electrostatic phototechnology techniques. More particularly, as
6 described in our aforesaid U.S. Patent 5,699,649, the ability of powders to acquire an
7 electrical charge advantageously is utilized for precisely measuring exact microgram
8 quantities of the powder, whereupon these exact microgram quantities are then placed
9 in individual containers, and the containers sealed.

10 Electrostatic charge has been employed to attract a given quantity of powder to a
11 surface. An example of this is the laser printer or the electrostatic copy device where a
12 drum is charged and toner particles are attracted and held in position by the charge.
13 The charge on the drum is neutralized by the attracted toner powder, thus limiting the
14 amount of toner in accordance with the charge image on the drum. The charged
15 powder on the printer drum is then transferred to a sheet of paper or other carrier to
16 give a final image. In our U.S. Patent 5,699,649, electrostatic charge technology is
17 employed for transferring a predetermined amount of a finely powdered
18 pharmaceutical or drug to a carrier or an intermediate such as a drum, carrying a
19 charge of predetermined intensity and area, rotating the charged drum surface, carrying
20 the predetermined amount of powdered pharmaceutical or drug on its surface, to a
21 transfer station where the charge is overcome and the dry powder is transferred to a

1 package which is then sealed. In lieu of a drum, a belt, or other movable surface is
2 charged to a given potential in a localized area. Alternatively, a predetermined amount
3 of powdered pharmaceutical or drug may be deposited directly in a package using
4 electrostatic charge technology.

5 When a given amount of a powdered pharmaceutical or drug is to be packaged,
6 the charge and area of charge can be determined experimentally for each dose of
7 pharmaceutical or drug and each particle size distribution. This can be done by
8 controlling either the charged area for a given charge density or the total electrostatic
9 charge on any individual charged area. These conditions can be adjusted to provide
10 essentially the exact desired amount of the particular pharmaceutical or drug to be
11 transferred at the transfer station.

12 In our U.S. Application Serial No. 09/097,104, we describe another electrostatic
13 charge technology which may be adopted to be used for measuring and packaging unit
14 doses of a pharmaceutical or drug in a readily ingestible form, i.e. as a tablet or capsule.
15 The technology thus described also permits reproducible precise measurement and
16 packaging of a pharmaceutical or drug, and which may be scaled from laboratory to
17 pilot plant to full scale production without the need for recertification.

18 Brief Description of the Invention

19 In accordance with one aspect of the present invention, controlled quantities of
20 powdered medication are formed in controlled release packages using electrostatic
21 metering technology. The present invention also provides, in another aspect,

1 combination medication delivery systems in which the active ingredients are segregated
2 from one another

3 Brief Description of the Drawings

4 Further features and objects of the present invention will become clear from the
5 following detailed description taken in conjunction with the accompanying drawings,
6 wherein like numerals depict like parts, and wherein:

7 Fig. 1 is a schematic flow diagram showing the various steps involved in
8 practicing the present invention;

9 Fig. 2 is an enlarged cross-sectional view of one embodiment of a controlled
10 release tablet made in accordance with the present invention;

11 Fig. 3 is a view, similar to Fig. 1, and showing alternative steps involved in
12 practicing the present invention;

13 Fig. 4 is a view, similar to Fig. 2, and showing an alternative form of a controlled
14 release tablet made in accordance with the present invention;

15 Fig. 5 is a view similar to Fig. 2, and showing yet another alternative
16 embodiment of the present invention;

17 Fig. 6 is a view, similar to Fig. 2, and showing yet another embodiment of the
18 invention; and

19 Figs. 7 - 9 are views similar to Fig. 2, and showing yet other embodiments of the
20 present invention.

21 Detailed Description of the Invention

1 Referring now to Fig. 1, there is a schematic flow diagram of the various pieces of
2 equipment needed to perform in the total process from powder supply to packaged
3 pharmaceutical or drug, i.e. in controlled release tablet form, containing a specified
4 amount of pharmaceutical or drug powder in the tablet or package. At 16 is indicated
5 the pharmaceutical or drug powder supply which is fed into a device 18 for creating an
6 aerosol of the powder. Next the powder particles are ionized at 20. As will be indicated
7 later, a number of these steps and pieces of equipment can be combined. At 24 is
8 indicated a carrier surface capable of maintaining a space charge on its surface. This
9 can be a plastic belt, for example, or a selenium drum of the type used in Xerox TM
10 photocopiers. This carrier surface 24 is passed through a charging station 25 where a
11 predetermined electrostatic charge 25A (an electrostatic "image") is created on a
12 predetermined area of the transfer surface. This charged surface 25A then passes
13 through a step 26 wherein powder is deposited on the carrier surface in a sufficient
14 amount 26A to neutralize the charge carried by the carrier surface. Thereafter, the
15 carrier surface, carrying the predetermined amount 26A of powder on its surface, is
16 passed to a powder discharging device 30 which discharges the powder 26A from the
17 surface 24 onto a membrane 29. Alternatively, the powder may be placed directly onto
18 the membrane 29. The membrane 29 containing its charge of powder 26A, then passes
19 through a sealing step 32 wherein a second membrane 34 which may be porous,
20 permeable or semi-permeable covers and seals the discharged powder 26A on the

1 membrane 29. There is thus produced an aliquot of powdered medicine 26A
2 sandwiched between semi-permeable or permeable membranes 29 and 34.

3 This sandwiched material is then passed to a cutting station 38 wherein the
4 sandwich is cut into individual tablets or wafers 36.

5 As mentioned previously in discussing Fig. 1, the carrier surface with the
6 electrostatic charge carries a known amount of charge on its surface and the polarity of
7 this charge is opposite to that of the powder particles suspended in the chamber. The
8 charged particles migrate to the charged surface because of the attraction by the
9 opposite nature of the charges. This migration of the particles continues until the
10 charge on the carrier surface is neutralized.

11 The actual amount of powder mass transferred to the carrier surface is a function
12 of the mass-to-charge ratio of the charged particles. Although it is difficult to achieve a
13 linear relationship between the mass and the actual charge, it is possible to establish a
14 fixed relationship between the surface area of the powder particles and the charge the
15 powder particle is carrying at charge saturation. However, the surface area of a mixed
16 group of powder particles of different sizes and shapes can be extremely difficult to
17 calculate mathematically, particularly when the shapes are irregular, (e.g. non-spherical,
18 microcrystalline, etc.) As mentioned earlier, the simplest method of determining the
19 amount and area of charge to attract a given weight of particles is to estimate the correct
20 area and charge and then apply the estimated charge to the estimated area on the carrier
21 surface 24 and expose this selectively charged area to a mass of powder which has been

1 ionized in the ionizing step. The amount of powder deposited can then be readily
2 measured at the discharge step. Thereafter, either the size of the charged area or the
3 amount of charge applied to the area at the charging station 25 can be adjusted
4 upwardly or downwardly to provide the correct amount of charge, both in area and
5 charge intensity, for picking up a desired weight of oppositely charged powder.
6 Likewise, using the technology of our co-pending application Serial No. 09/097,104,
7 larger quantities of medication may be deposited.

8 A feature and advantage of the present invention is to produce carefully
9 controlled doses of controlled release medication. Electrostatic metering and packaging
10 as above described permits exact dosing. And, by employing selected porous,
11 permeable or semi-permeable membranes for encapsulating the powdered medicine
12 aliquots, drug release rate and also site of drug release can be determined by adjusting
13 membrane material and/or membrane thickness.

14 The membranes should be formed of ingestible materials having a selected
15 permeability porosity to fluids at a selected site or sites within the alimentary canal, so
16 as to permit controlled release of the medication. By way of example, one or both
17 membranes 29, 34 may comprise acid-dissolvable materials when it is desired to release
18 the medication into the stomach or the membranes 29, 34 may be alkaline-dissolvable
19 materials at differing pH's to release into chosen locations within the intestine.

20 Porosity, membrane thickness, etc., may be selected to provide desired rate of
21 dissolution at the site of interest.

1 The invention is susceptible to modification. For example, referring to Figs. 3
2 and 4 by adding a second powdered medicine supply and discharge station (shown
3 generally at 40), a two-component controlled release tablet 48 may be formed (see Fig.
4 4) incorporating two different powdered medicines 50, 52, encapsulated between
5 membranes 29 and 34 for simultaneous controlled release.

6 Alternatively, as shown in Fig. 5, two different drugs 60, 62 may be layered on
7 one another, separated by a membrane 64 so the two medications may be delivered
8 sequentially either in the same location, or in different locations within the alimentary
9 canal. Another feature and advantage of the multi-drug tablet of Fig. 4 and Fig. 5, as
10 will be discussed in detail herein below, is that two normally incompatible drugs may
11 be to be safely packaged in a single tablet.

12 The invention is susceptible to modification. For example, individual doses may
13 be formed by electrostatic deposition in accordance with U.S. Patent No. 5,714,007.

14 Other possibilities are possible. For example, referring to Fig. 6, the tablet 70 may
15 incorporate an adhesive layer 72 such as a mucosal adhesive, which in turn is covered
16 by an acid or alkaline dissolvable protective membrane 74, which dissolves at a selected
17 site allowing the adhesive to adhere, for example, to the intestinal wall, thereby
18 increasing residence time of the medication in a chosen location. Alternatively, an acid
19 or alkaline activatable adhesive may be applied to the outer surface of the tablet. In yet
20 another possibility, the membrane may be a material which expands on contact with the

1 acid or alkaline in the alimentary canal and becomes more porous whereby to slowly
2 release medication in a chosen location within the alimentary canal.

3 As mentioned above, a particular feature and advantage of the present invention
4 is that it permits packaging, within a single tablet of two or more different drugs
5 normally considered to be incompatible. Certain drugs are known to cause undesirable
6 side effects which need to be countered by a second drug. For example, Omeprazole¹
7 which finds substantial utility as an oral antiulcer agent, also is known to block the
8 release of B12 from its protein binding site in food. This can lead to pernicious anemia.
9 The present invention permits packaging of time-release Omeprazole with Vitamin B12
10 in an appropriate dosage of, e.g. 25µgm - 1 mg. After taking the medication, one
11 membrane will dissolve allowing absorption of the B12, while the remaining membrane
12 package carrying the Omeprazole will pass into the small intestine where the drug is
13 released and absorbed.

14 The invention is susceptible to modification. For example, while the membranes
15 have been described as being preformed, permeable, semipermeable or porous material,
16 one or both membranes could be formed in place from a gel or liquid.
17 The ability to accurately place the dose of medication onto a plurality of substrates and
18 seal the dose with other membranes in accordance with the present invention, allows
19 for the fabrication of many different dosage forms; by altering the substrates and
20 encapsulating material a single unit dose form can be fabricated with a plurality of
21 different drugs in different coverings, membranes and barriers. This will provide a

1 single dosage form with multiple active ingredients each being delivered to the
2 appropriate site for absorption. Alternatively, two or more active medicaments may be
3 combined in a single delivery container, i.e. pill, capsule or caplet without actually
4 mixing the two or more ingredients. For example, referring to Fig. 7, the active
5 ingredients are segregated from one another in a compartmentalized capsule 100.
6 Alternatively, two or more tablets 102, 104 each containing only one active ingredient,
7 could be placed in a larger absorbable capsule or encased in a larger tablet 106. Or, as
8 shown in Fig. 9, two or more active ingredients could each be formulated as
9 encapsulated particles 108A, 108B, and the encapsulated mixed particles placed in a
10 capsule 110 where the only contact is between the particle inert coatings, etc.

11 There are many drugs which could benefit from combinations to improve patient
12 benefit. However, with many active ingredients, there is a question of chemical
13 interaction. Thus, several drugs are normally prescribed as separate tablets or capsules
14 which presents a problem in terms of patient compliance, e.g. TB triple therapy, AIDS
15 multi-drug therapy, anti-infectives, etc. Also, delivery of two or more active
16 medicaments could reduce side effects, and/or improve therapeutic response which
17 may in turn permit a decrease in the required dosage. By way of example, we provide
18 the following combinations:

19 (1) Omeprazole¹ and analogs and isomers - As noted above Omeprazole is
20 an inhibitor of gastric secretion and also inhibits the absorption of certain
21 drugs/compounds that require stomach acid such as Vitamin B12, the deficit of which

1 results in pernicious anemia. A combination of B12 with Omeprazole would eliminate
2 the potential problem.

3 (2) Valacyclovir² and analogs and is used to treat Herpes Zoster. It is well
4 known that two ^{drugs} Cimetidine³ and Probenecid⁴ both increase the AUC (area under
5 curve) and Cmax. A combination drug can be constructed with a combination of either
6 one or more of these components to provide more efficacy.

7 (3) Enalapril⁵ and analogs and isomers is an ACE inhibitor used for the
8 treatment of hypertension. This drug has been used with the following and analogs
9 and isomers beta adrenergic-blocking agents, methyldopa, nitrate, calcium blocking
10 agents, hydrazine, Prazosin⁶ and Digoxin⁷ without clinically significant side effects.
11 One or more of these agents may be combined with Enalapril to improve the
12 compliance of patient with hypertension and hypertension and other cardiac diseases.

13 (4) Ketoconazole⁸ and analogs and isomers is used to treat fungal infections.
14 One of the side effects is the reduction of Testosterone. This side effect could be helped
15 by the combination of Testosterone or one of its isomers or analogs to overcome the side
16 effect.

17 (5) Omeprazole¹ and analogs and isomers is also used in combination with
18 Clarithromycin¹ for ulcer treatment. These two drugs may be combined as a single
19 dose for patient compliance.

20 (6) Tamoxifen¹⁰ and analogs and isomers used in treatment of breast cancer
has a +/- 30% incident of water retention with weight gain > 5%. This can be a

1 disturbing consequence for patients with an even more disturbing disease. The
2 addition of a diuretic or combination diuretic to form a single dosage form for reduction
3 in side effect and compliance.

4 (7) Isotretinoin¹¹ and analogs and isomers used for the treatment of postular
5 acne has a severe danger if taken by a woman who is pregnant. The incorporation of
6 oral contraceptive medication would eliminate the potential for pregnancy while
7 medicated.

8 (8) Metformin HCl¹² and analogs and isomers are hypoglycemic agents
9 which have been used in combination with Solfonylurea¹³ and analogs and isomers to
10 treat Type 2 Diabetes. These two agents act in different ways on reducing glucose
11 levels. A combination would be helpful for those patients requiring more aggressive
12 oral therapy for their diabetes.

13 It should be noted that certain combination drugs, including some of the above-
14 listed combination drugs, also may be blended and packaged in a single tablet or
15 capsule, when chemical interaction is not a problem.

16 The present invention also allows for the rapid production of different dosage
17 medications using the same active ingredient, and allows for the development of
18 medications with longer resident time.